An Initial Study of Using the 34-m Antenna for Lunar Missions Support

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ABSTRACT

As a part of the long-range planning of future Mars and lunar missions, a rudimentary study has been *made* of a 34-m antenna system with differentially pointed multiple beams. The performance loss mechanisms of the differentially pointed multiple-beam systems were identified and quantified. The goal is to determine the feasibility of using the 34-m antenna to supped widely separated elements associated with lunar missions.

i. INTRODUCTION

Telecommunication plans for most future planetary missions include use of 34-m antennas. For lunar missions, smaller antenna aperture sizes are also being considered since the communications distance is short and the relatively large angle subtended by the Moon at the Earth cannot be covered by the beamwidth of a 34-m antenna at X-band or Ka-band. Nevertheless, there is a good reason to consider using the 34-m antennas for lunar missions support, Le., the high interest within DSN in standardizing the 34-m beam waveguide (BWG) antenna as a platform for cross-mission support. Indeed, the Synthesis Group's "Report on America's Space Exploration initiative" (Ref. 1) assumed a lunar-Mars DSN cross-support strategy using 34-m BWG antennas with multiple differential pointing for lunar coverage.

To provide simultaneous coverages of several mission elements on the lunar surface, a number of feeds may be used on the 34-m antenna to realize a multiple beam system. The Earth-Moon geometry is shown in Figure 1. It is seen that the Moon sutends *a* half angle of 0.26 degrees at the Earth. As shown in the tabulation that accompanies the figure, this is equal to about 15 beamwidths (BWs) at Ka-band and 4 beamwidths at X-band. (Note that the Ka-band frequency of 32 GHz is used expediently in the computations of this study in the interest of obtaining quick approximate results, although this is not the frequency assigned for lunar missions support.

	Ka-BAND, 32 GHz	X-BAND, 8.45 GHz
BEAMWIDTH OF BORESIGHT BEAM BW	0.016 deg	0.083 deg
SCAN RANGE TO LUNAR LIMB*	15.3 BW	4.1 BW

*ASSUMING ANTENNA BORESIGHTED ON CENTER OF MOON.

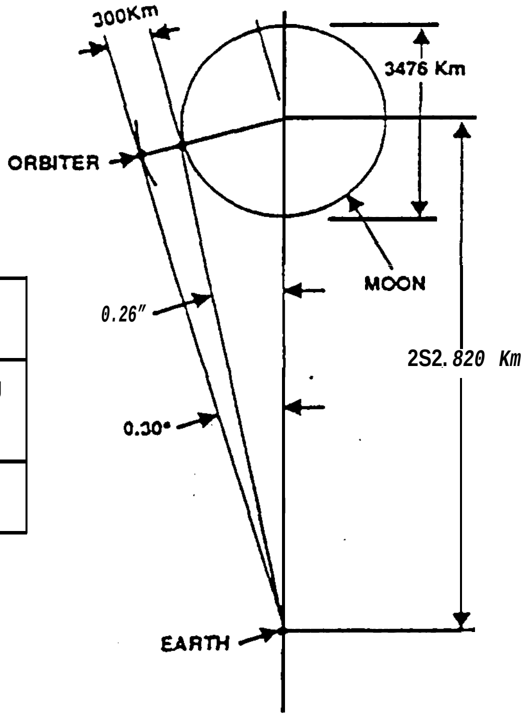


Figure 1. Earth-Moon Geometry

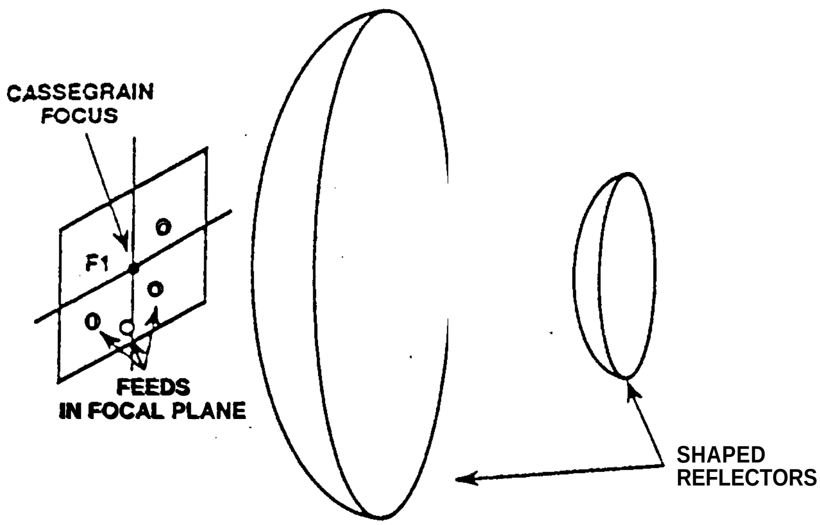
The large number of beams needed to cover the angle space from the antenna boresight to the lunar limb leads one to expect substantial performance losses, especially at Ka-band, of the 34-m multiple beam antenna system. One well-known performance loss is "scan loss," which refers to the loss of gain of the scanned beams as compared to the boresight beam. Fora reflector-antenna type multiple-beam system, the severity of the "scan loss" is generally proportional to the number of beamwidths scanned, although not generally in a simple linear relationship.

The fact that the Ka-band beam which covers the lunar limb would be scanned 158W raises the question of the feasibility of using 34-m antennas for lunar mission support. On the positive side, the 34-m antenna starts with a much higher boresight gain compared to a smaller antenna.

The purpose of the present study is thus to quantify the rudimentary performance of a 34-m multiple beam antenna system in order to aid in planning the next phase of studies. It is noted that no serious study has been made of the DSN 34-m antenna scanning characteristics and no current database exists on the 34-m antenna scanning characteristics.

. II. THE ANALYTICAL MODEL

The analytical model is shown in Figure 2. The antenna model is the 34-m Cassegrain dual-shaped reflector design of DSS-13. A number of feeds, each generating a beam in the far field, are assumed to be in the focal plane at the Cassegrain focus. It is assumed that the antenna is boresighted at the center of the Moon and the feeds are movable by mechanical means in order to cover moving mission elements on the Moon.



THE MODEL:
1. DSS-13 34-M DUAL SHAPED REFLECTOR ANTENNA
2. SINGLE FEED PER SEAM

CALCULATION MATRIX:
1. FREQUENCIES: 32GHz AND 8.45 GHz
2 FEED POSITION OFFSET: IN FOCAL PLANE

Figure 2. Analytical Model

Clearly, this isa rudimentary multiple-beam system whose performance can be significantly improved upon by a number of means, given more study time. However, this first study has the limited goal of establishing ballpark performance data for a simple 34-m multiple beam antenna. More complex systems and more elaborate analysis efforts can be undertaken in the next phase of study.

III. BEST- AND WORST-CASES IN MULTIPLE-BEAM ANTENNA GAIN LOSSES

The best- and worst-case scenarios in using a reflector antenna-based multiple-beam system to support lunar missions are shown in Figure 3. The best case is when all mission elements on the lunar surface are widely separated in angle space, Figure 3(a). Each mission element can then be supported at the peak gain point of a beam of the antenna. The worst-case scenario is when three or more mission elements are closely spaced and can only be supported by two beams from two side-by-side horns, as shown in Figure 3(b). In this case, it is not possible to support the three mission elements by using three beams because there is a minimum of spacing between adjacent beams, imposed by the finite physical size of the feedhoms. In the very worst case, show in Figure 3(b), one mission element is located in the direction where the two beams cross over. This scenario would sustain a somewhat higher loss than if it can be supported by the peak gain of some beam.

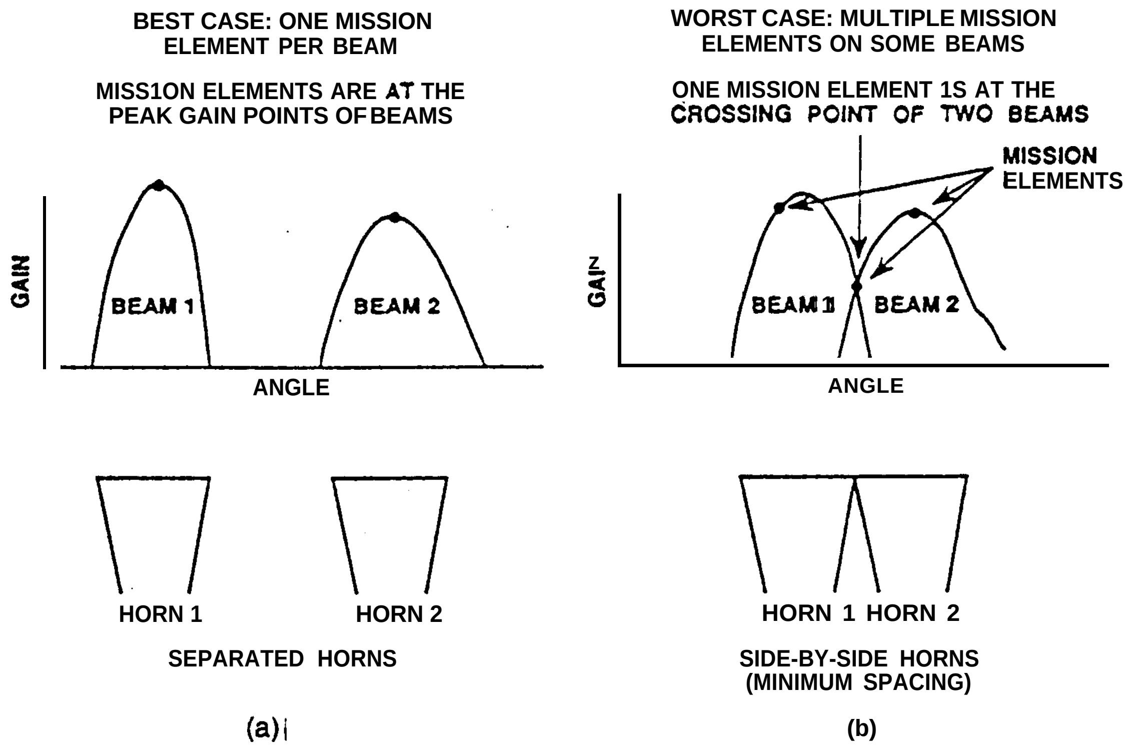


Figure 3. Best and Worst Cases (34-m Antenna Performance Losses)

In Figure 4, the radiation patterns due to four Ka-band side-by-side horns in the 34-m antenna are shown. The first horn is positioned at the Cassegrain focus and gives the boresight beam of the antenna. The best-case antenna gain loss characteristics for supporting a lunar mission is the envelope connecting the peak gain point of the individual beams in Figure 4. The envelope of the peak gain of the beams gives the gain vs. scan angle curve, defined as the "scan loss" in reflector antenna literature. The worst-case gain loss is seen to be the locus connecting the cross-over point of the main beams generated by side-by-side horns. It is seen that the difference between the best and worst case gain loss is at a maximum near the antenna boresight. This is an aspect of multiple-beam antennas that may not be as well recognized as the "scan loss" but certainly needs some attention in future studies and designs.

The cross-over level of the first two beams is approximately -15 to -16 dB down from the peak gain of the boresight beam. This is a larger loss than the scan loss from bore-sight to lunar limb in the X-band case, and thus can lead to potentially bad surprises for lunar missions if not attended to properly.

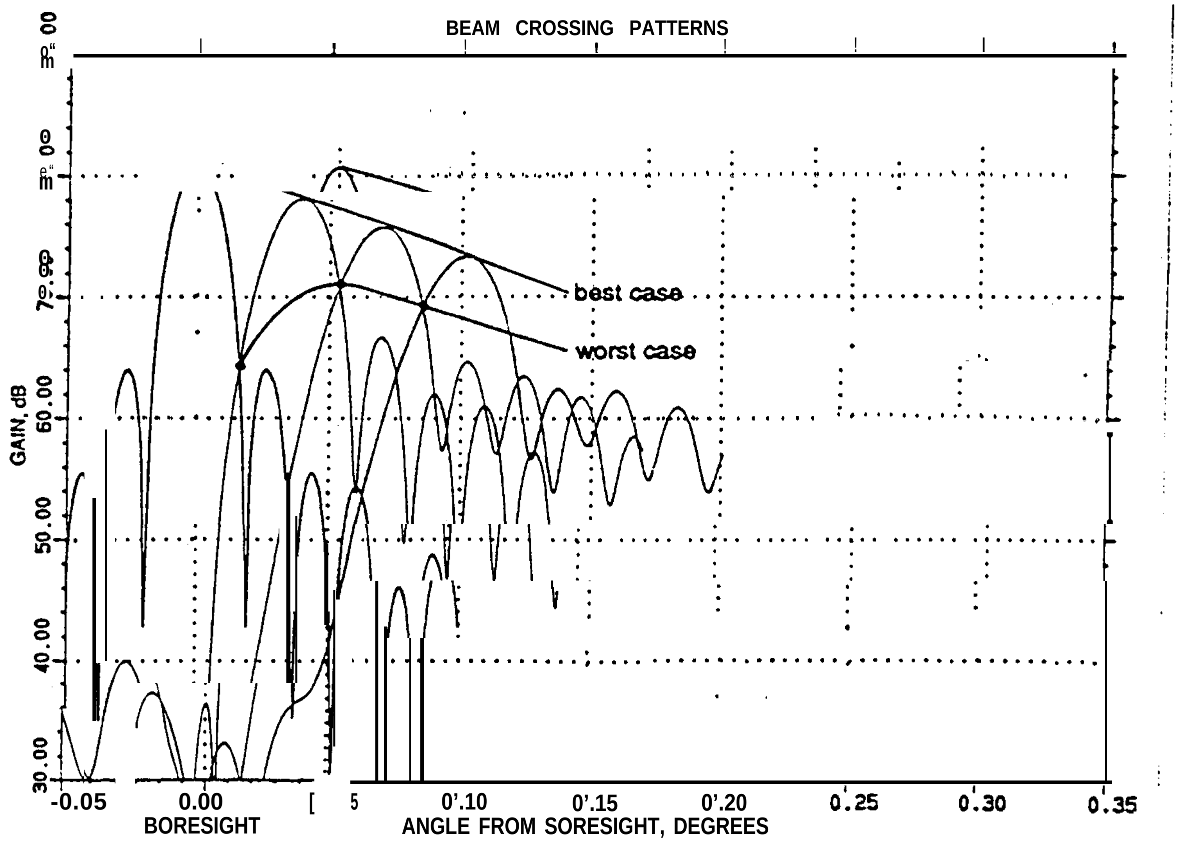


Figure 4. 34-m Antenna Scan Patterns, Ka-band (32 GHz)

IV. SUMMARY

The 34-m antenna performance loss vs. scan angle characteristics have been established using a simple multiple beam system model. In addition to quantifying the "scan loss" curves at X- and Ka-band, the beam-cross levels at small angles are identified as a potential problem that needs some design attention. More detaiied results of the study will be presented.

REFERENCES

1. Synthesis Group, "America at the Threshold,"= on America's Space Exploration Initiative, Superintendent of Documents, US Government Printing Office, Washington, DC, 1991.